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An investigation into the spectral content of pop music

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Summary

In the design of a high-level studio monitoring loudspeaker, account must be taken of the type of programme that will be fed to it. When used to monitor pop music, which may contain relatively high levels of low frequencies, the maximum sound pressure level obtainable may be restricted by cone-movement limitations to a value which is unacceptably low for the studio manager to obtain the correct music balance.

This report describes an investigation in which some pop music known to contain the highest likely low-frequency content was analysed to obtain its spectrum. From this information, a curve was derived which will replace the previously used criterion as a basis for future designs of high-level monitoring loudspeakers.

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1. Introduction

In a loudspeaker system, the sound pressure level produced by the low-frequency drive unit is determined by the amplitude of vibration of the cone and the frequency of the excitation signal. For a given sound pressure level, the amplitude of vibration of a cone of given size in a closed cabinet is inversely proportional to the square of the frequency. Although this relationship is somewhat modified for a vented cabinet the same trend applies. The maximum sound pressure level that can be obtained from a bass unit of given size and given excursion when fed with a wideband signal is therefore determined by the amplitude of the signal spectra in the bands 25 – 200 Hz relative to that above 200 Hz. It is therefore important, when designing a high-level studio monitoring loudspeaker, to know the spectral content of the programme material which the loudspeaker is intended to reproduce.

This report describes a short investigation to obtain the spectra of programmes which are known to contain high levels at low frequencies.

2. Restriction of sound pressure level by low frequency content of the signal

Fig. 1 shows a typical example of the relationship between sound pressure level and the frequency of excitation when a 300 mm bass unit in a vented cabinet undergoes a constant cone excursion of ±3 mm. From this curve, it will be seen that when a programme signal having an appreciable low-frequency content is fed to a bass unit, the maximum value of the overall unweighted sound pressure level (dB_{Lin}) that can be generated from that unit will be determined by both the physical constraints on cone excursion and the spectral amplitude distribution of the signal within the lower frequency bands.

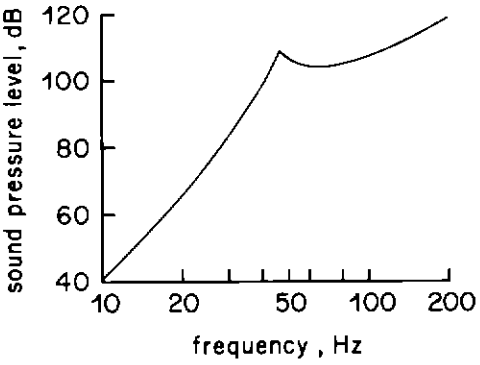

Fig. 1 - Sound pressure level obtainable from a 300 mm bass unit in a vented cabinet. Voice coil excursion ±3 mm

The maximum excursion of the cone of a bass unit will eventually be restricted by mechanical constraints such as those imposed by the suspension. However, in most cases, before this limit is reached distortion will be generated when the voice coil leaves the magnetic field, the point at which this occurs being dependent on the relative length of the voice coil and the thickness of the pole pieces. Since an early step in the design of a bass unit is to estimate the required excursion of the cone, it is essential that the required overall unweighted sound pressure level (dB_{Lin}) be known together with the amplitude of the signal spectra in the bands 25 – 200 Hz relative to that above 200 Hz in the wideband signals that will normally be fed to the loudspeaker.

3. Previous analyses of programme spectra

During development of the LS5/5 monitoring loudspeaker in 1967, a peak octave analysis of programmes was made[1] to determine their relative bass content. This information was used to find the maximum allowable bass lift which could be applied by an equaliser preceding the power amplifier before the onset of peak clipping in the amplifier. It showed that there was a slow but steady decrease in peak signal levels at frequencies below about 200 Hz. In 1973, a survey of studio and control room sound pressure levels was carried out[2] to assist in the revision of sound insulation criteria. This showed that for pop music the sound pressure levels in the bands below 80 Hz were lower than at mid-band.

However, in recent years, it has been noticed that the sound levels of reproduced and live pop music have been rising and that very high levels at low frequencies have been reported by various workers.[3] In order to update our knowledge of pop music spectra the present investigation was undertaken. Worst-case figures were needed to enable calculations to be made of the maximum cone excursion required of a loudspeaker.

4. Pop music survey

A stereo pop-music balancing session in the control room of studio 4 at the BBC's Maida Vale premises was attended and calibrated audio tape recordings were made of the electrical signals fed to the monitoring loudspeakers. The session was chosen on the advice of BBC programme personnel to ensure that the programme would contain the highest level of low-frequency energy likely to be encountered during programme balancing.

The recordings were made on a high quality tape recorder whose response extended down to 10 Hz.

5. Analysis of recordings

The spectral analysis was carried out using equipment designed for the survey referred to earlier.[2] A full description of the apparatus and computer programme are contained in the reference and only a brief outline will be given here.

The recordings were analysed by a one-third octave, real-time spectrum analyser which was arranged to sample and digitize the voltage levels in each band in turn at a rate of 30 complete spectra per minute. The digitized samples were later analysed by a computer programmed to give the level in each one-third octave band which was exceeded for a given percentage of time. The 1% values were chosen, in the present case, rather than the maximum values in an attempt to exclude spurious clicks etc. The analysis extended from 25 Hz to 10 kHz.

Because the recordings were made during a working session and various mixing-desk controls were liable to be adjusted, it was necessary to choose the extracts of programme for analysis with care in order to obtain passages during which the controls were not being changed. The extracts chosen have been designated A, B, C, etc. for reference and are detailed in the Appendix.

6. Results

The results of the analyses are shown in Figs. 2 and 3. Fig. 2 shows the signal voltage applied to the left-hand loudspeaker for three recorded extracts A, B and C. Fig. 3 shows the signal voltage applied to the right-hand loudspeaker for four recorded extracts D, E, F and G. The curves for extract C of Fig. 2 and extracts F and G of Fig. 3 are directly comparable since they are all recordings of the same item of music reproduced at different times throughout the session.

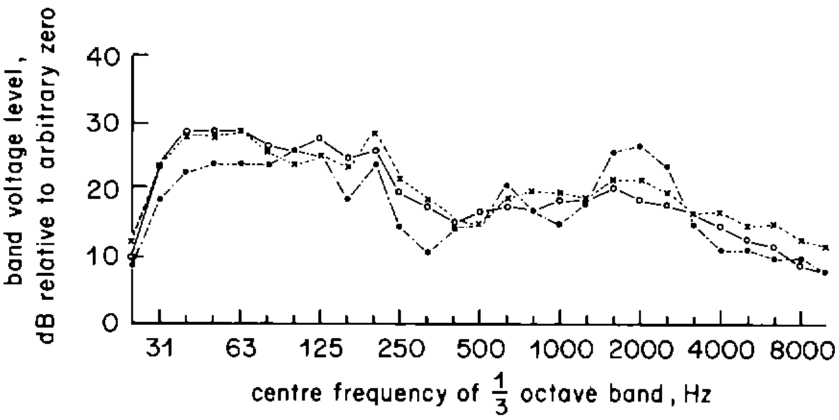

Fig. 2 - Band levels exceeded for 1% of time — left-hand loudspeaker

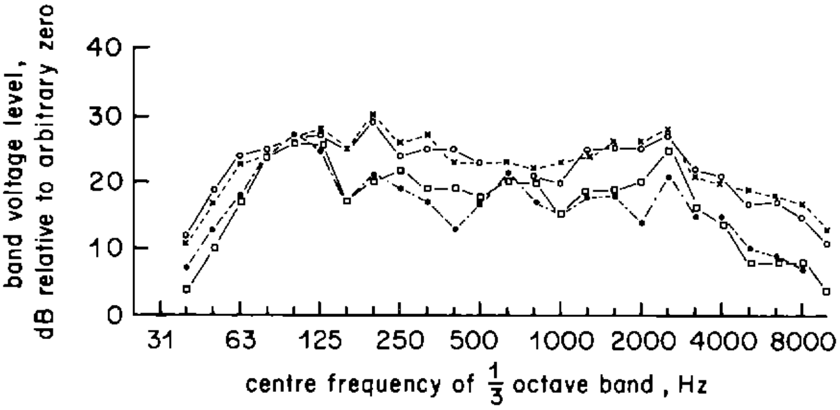

Fig. 3 - Band levels exceeded for 1% of time — right-hand loudspeaker

It can be seen that there is a much higher level at low frequencies in Fig. 2 than in Fig. 3. This is not altogether surprising as the drum kit for this session was being 'panned' to the left-hand side of the stereo stage. Also, both Figs. 2 and 3 show consistently higher low-frequency contents than would be expected on the basis of the previous work already mentioned.[1,2] It is clear from a comparison of these spectra, that the signal with the spectrum of Fig. 2 will restrict the maximum sound pressure level obtainable from a given bass unit to a greater extent than a signal having the spectrum of Fig. 3.

The sampling method used in this investigation will introduce errors into the results. Meares[2] quotes 1.8 dB as the average standard deviation of individual spectrum values over the whole spectrum. The likelihood is that in the present study the standard deviation of the values will be lower than 1.8 dB because the sampling rate used was three times as great as in the work quoted above. Also, in the present case, each recorded extract was analysed twice giving twice the number of samples to the computer. Therefore, although the total quantity of analysed programme material was rather small it was felt to be sufficient to give the required information with an adequate degree of accuracy.

7. Discussion of results

During the development of a loudspeaker system, a number of different programme tape recordings are used to assess various loudspeaker characteristics. For example, recordings of speech and music played at normal levels are used to assess tonal quality. For a high-level monitor, pop music recordings played at high levels are used to assess the ability of the system to achieve the designed maximum sound pressure level. Fig. 4 shows the spectrum of the high-level pop music test-tape used until recently and which was thought to be typical of this type of music. A comparison of the spectrum of Fig. 4 with that of Figs. 2 and 3 show it to be rather similar in shape to Fig. 3. However, a typical sample of pop music is not what is wanted. Clearly, a future high-level pop music test-tape should have a spectrum similar to that of the worst case found in the present study if the loudspeaker system is to be tested realistically.

Fig. 5 shows two curves; curve (a) shows the spectrum of the maximum levels likely to be present in a pop music signal and curve (b), for comparison, shows a peak analysis of programmes obtained from Reference 1. Curve (a) was derived from Figs. 2 and 3 by taking the highest value in

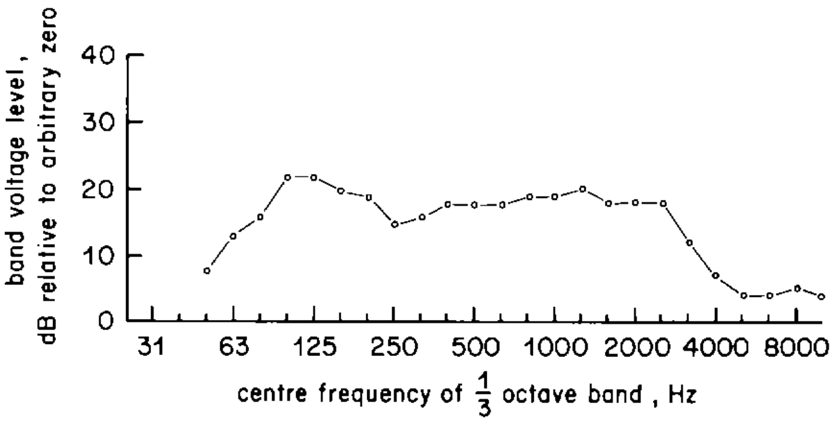

Fig. 4 - Band levels exceeded for 1% of time during pop music item formerly used as a test tape

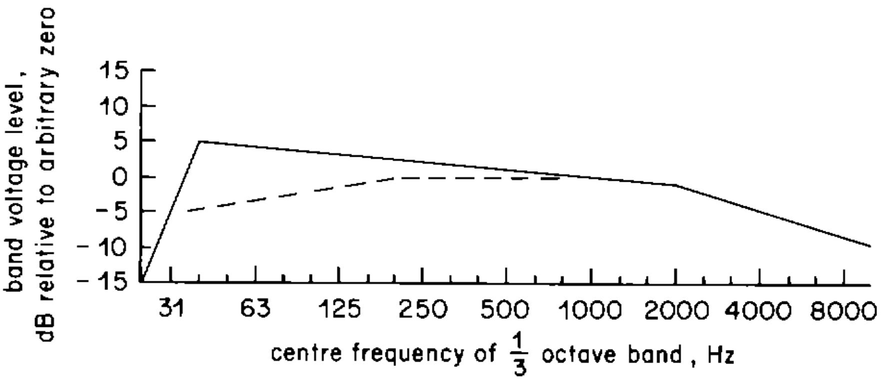

Fig. 5 - Spectrum of maximum levels likely to be present in a pop music signal

——— **(a) derived from analysis of programme in present report**

- - - - **(b) Obtained from analysis of programme 1967** the bands 25 – 200 Hz and the average value above 200 Hz. A smoothed curve was then drawn through these points. A comparison of the curves shows that the 40 Hz band level of curve (a) is 5 dB above the mid-band level whereas with curve (b) the 40 Hz band level is 5 dB below the mid-band level. This implies that a loudspeaker designed on the basis of the earlier study might be restricted in its maximum sound pressure level capability by a factor of 10 dB when being used to monitor modern pop music. Clearly, the present results are the more relevant.

8. Conclusions

A short investigation has been carried out in order to obtain up to date information about the spectra of pop music likely to be fed to a monitoring loudspeaker.

An idealized curve for the spectrum of pop music has been produced which should be used in future as a basis for the design of high-level monitoring loudspeakers. This curve shows that the low-frequency band levels may on occasions be higher rather than lower than the mid-frequency band levels. This fact may also be relevant in the design of other items in the broadcast chain such as transformers and limiters.

A new test tape recording will be used in future in the BBC for high-level testing of loudspeakers. This will consist of the extract of music found in the present study to have the highest low-frequency content.

9. References

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Appendix

The table shows for reference the duration and whether the extract was recorded during a recording take or playback.

Loudspeaker	Musical extract	Duration Min. Sec.	
Left hand	A	1.40	Take
	B	2.25	Playback
	C	2.10	Playback
Right hand	D	2.35	Playback
	E	1.45	Take
	F	2.20	Take
	G	0.50	Playback

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